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ABSTRACT

This paper provides a rationale for the selection of illustrations and visual aids for the classroom. The theories that describe the processing of visuals are dual coding theory and cue summation theory. Concept attainment theory offers a basis for selecting which cues are relevant for any learning task which includes a component of identification and recognition. Selection strategies, methods for concept attainment, are used when the learner is able to choose the order of instance. Reception strategies are used in the more realistic unpredictable, random instance presentation. Experiments that tested individual choice of selection and reception strategies resulted in the following suggestions to consider when choosing an illustration: instructional pacing; previous experience; and field dependence. Supportive evidence also discusses the effects of pacing; level of prior knowledge; and field dependence and visual learning. It is concluded that the application of concept attainment theory to future research may allow more precise and informed choices of illustrations, as well as suggesting use of types of illustration previously unconsidered. (Contains 34 references.) (DGM)

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Toward a New Theory for Selecting Instructional Visuals

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Introduction

The value of using images in memory tasks has been written about since the early Greeks. Similarly, the finding that memory for pictures is superior to memory for words, (Shepard 1967) has been so consistent that it has been called the "picture superiority effect" (Levie, 1987). In applied settings however, studies involving visuals have often been plagued by those problems which characterized most early media studies: weak conceptualization and poor research design.

In terms of weak conceptualization, Clark's (1983) seemly straightforward criticisms of the "media against media" or mediated versus "traditional" instruction have been surprisingly controversial and much discussed. These arguments notwithstanding, such studies were not grounded in theory and are probably best construed as evaluations, (Moore, Myers, & Burton, 1994). As such, they provided no theoretical information ("this works as good as, or better than, this"). The second problem, that of poor research designs, has been covered in depth by, for example Dwyer (1978), and involves the omission of experimental controls, non-equivalent conditions, etc. While the storage of images *per se* in memory remains controversial, a few notions about images and visuals are generally agreed upon in the cognitive psychology literature.

In whatever manner images are stored, our memory for visuals is not very exact. Images contain information encoded after perceptual processing has taken place. As a result they tend to be generalizations or the gestalt of visuals (Klatzky, 1980) which have been reorganized to "fit" (Anderson, 1978). Furthermore, as with any item in long-term storage, memory for visuals is subject to distortions and forgetting (Miller & Burton, 1994). Visual processing takes place in the same limited system as that for all other stimuli. The system can only process a fraction of those stimuli that bombard it at any one time, and consequently our processing of visuals is limited (Kosslyn, 1975).

The two currently accepted cognitive theories describing the processing of visuals are dual coding theory and cue summation theory. Dual coding theory (Paivio, 1971,

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1986) is the notion that concrete sensory stimuli which can be verbalized, *will* be verbalized. Concrete words which can be imaged, *may* be imaged. Thus visuals are decoded into words automatically and stored in *two* channels. This is the most popular explanation for visuals tending to be more effective than words.

Cue summation has been the driving theory behind the bulk of the research in the effort to explain why some visuals work better than others. In its simplest form, what Dwyer (1978) has called "realism," this theory predicts that "learning will be more complete as the number of cues in the learning situation increases.... An increase in realism... increases the probability learning will be facilitated" (p. 6). Unfortunately, Dwyer's review of some 50 studies found that increasing the number of cues (adding realism) often *decreased* learning.

Miller (1957) had, in fact, allowed for just such an occurrence (albeit in a behavioral, rather than cognitive framework).

> When cues...within the same modality are used simultaneously, they may either facilitate or interfere with each other. When cues elicit the same responses simultaneously...they should summate to yield increased effectiveness. When the cues elicit incompatible responses, they should provide conflict and interference (Miller 1957, p. 78).

The problem, of course, is determining which cues will summate and which will produce conflict and interference. Severin (1967), also agreed that learning would be increased as the number of cues, particularly visual cues, increased. Severin added to the above sentiments by emphasizing that the cues added had to be *relevant* ones. Hsia (1968, 1971) expanded on this by stating that they not only had to be relevant, they had to be *redundant*. If "more is better" works only some of the time, then how to decide more (or less) of what? How to decide what is relevant? Concept attainment theory, as described by Bruner, Goodnow, and Austin (1956) offers a basis for selecting which cues are relevant for any learning task which includes a component of identification and recognition.

Concept Attainment Theory

Bruner, Goodnow and Austin(1956) describe the definitive efforts in a formal description of *concept attainment*, which they define as

> ...the process of defining attributes that distinguish exemplars from non-exemplars of the class one seeks to discriminate. (p. 22)

An attribute is "any discriminable feature of an event that is susceptible of some variation from event to event"(p. 26). In other words, if the feature is constant between classes, it is not a meaningful attribute for the task at hand. Concept attainment is learning which involves categorizing items based on some of their features.

The manner in which individuals learn a concept—the strategy used—is influenced by a

variety of factors, including (but not limited to) the nature of the task, the type of feedback received, and the time available for learning. Strategy choices in turn affect the time required for accurate concept attainment. Bruner, Goodnow, and Austin (1956) describe *selection* strategies and *reception* strategies. Selection strategies are methods for concept attainment when the learner is able to choose the order of instance. Reception strategies are used in the more realistic instance of unpredictable, random instance presentation. Experiments involving participants trying to learn a concept represented by a specific pattern of shapes, borders, and colors on cards were used to test the effectiveness and frequency of strategies in situations permitting selection and situations which dictated reception.

Selection Strategies

These authors describe four hypothetical ideal strategies for selection. "Ideal" in this case refers not to effectiveness but to the hypothetical purity. This is acknowledgment that humans are unlikely always to use the same machine-like approach to a task. The first strategy is "simultaneous scanning," in which the individual generates all possible hypotheses (combinations of attribute values) and eliminates hypotheses as evidence arises. In "successive scanning," the second strategy, the individual chooses a single hypothesis and then selects examples to test that hypothesis until accepting it or having to reject in favor of another hypothesis. The third strategy is "conservative focusing," and involves finding a single positive example of the concept, and then varying only single attributes in successive instances. If the variation results in a negative instance, then it is one of the defining attributes. A focusing strategy allowing more than one attribute to change between instances is "focus gambling," the fourth strategy (Bruner, Goodnow & Austin, 1956).

These authors' first experiment involved showing each participant a card which exemplified a concept. The viewer could then select a card from an array of 64 displayed on a board, and learned whether it also was an instance of the concept. Observations of the types of choices participants made allowed the experimenters to classify the strategy in use as a scanning or focusing strategy. Each participant solved three concept problems; two in the manner described above, and the third with no array of cards from which to select. The third problem provided a variance in the demand on memory. Those individuals who used the focusing strategy were able to solve the third problem in an average of five trials; the scanners required thirteen. This experiment showed that the focusing strategy is generally more effective, and also revealed that under the conditions of the experiment, humans without prompting use strategies akin to the ideal strategies presented, although the strategies generalize to just scanning and focusing.

A second experiment suggested the choice of strategy may vary depending on the presence of order in the selection of cards. If the array of cards was well-ordered, so as to encourage systematic testing of attributes, more of the students involved in the test used a focusing

strategy. If card presentation was totally random, more used scanning.

Reception Strategies

The conditions of the experiments used to test scanning strategies were somewhat unrealistic—humans usually have to take concept instances as they come, and do not have the luxury of modifying attributes to see if they are important. The researchers devised a second series of experiments to test strategy choice in the reception condition—when the learner must make the most of each instance as it presents itself in an arbitrary fashion.

The expected strategies were the "wholist" strategy (p. 131) and the "partist" strategy (p. 143). The wholist strategy is similar to focusing; the learner formulates an idea of the concept by using the entire first instance, and modifies it only when subsequent positive instances vary. The partist strategy is akin to scanning; the learner chooses a single attribute from the first instance, and then adds to it as subsequent examples warrant. If the single attribute chosen is ruled out by a negative example, then the learner reviews in memory all previous examples to formulate a new hypothesis.

The experiments testing these strategies, like those testing selection strategies, involved the use of abstract concept presented on cards (Bruner, Goodnow and Austin, 1956). A little more than half the participants used a wholist strategy (and half of these adhered to it faithfully). When time was a factor, the wholist strategy was vastly more effective, but both strategies worked equally well when there was no time pressure. For both strategies, as the number of attributes increased, the percentage of problems solved decreased. These results strongly reinforce the intuitive belief that minimizing complexity would be desirable in the presentation of concepts to novices.

Attaining Concepts in Material that Seems Familiar

In an experiment involving thematic material within the realm of experience of all the students participating, the authors noted some unexpected changes in behavior (Bruner, Goodnow and Austin, 1956). The experiment included two groups. One (the thematic group) used cards depicting an adult figure and a child figure. The attributes which varied were affect of each figure (angry or cheerful), gender of each, and mode of dress for each (night or day). The second (control) group's cards had the same number of varying attributes, but the figures were triangles or rectangles, and could be yellow or black, bordered or unbordered.

The average number of trials for the control group to correctly ascertain the concept was 6.1; for the thematic group it was 9.7. The ranges for the two groups were similarly disparate. Arithmetically, the two groups were solving the same problem—why should they differ so? The authors offer a precisely stated description of the intuition which comes to mind:

> ...the problem solver is likely to fall back upon reasonable and familiar hypotheses about the possible groupings. In so doing, he may be led into a form of successive scanning:

> the strategy par excellence for going through a list of hypotheses. ...thematic material will, more readily than abstract material, lead certain attributes to have nonrational criteriality: the subject will "hang on" to these and will formulate hypotheses around them. (Bruner, et al., 1956, p. 111)

What is implied here is of particular interest to anyone wishing to help others learn to categorize something which already seems familiar. To assist the learner in such cases requires some attempt to make the genuinely important attributes stand out enough to overshadow student preconceptions.

Individual Differences and Choice of Strategy

Besides the learning situation, is there any predictor of what strategy a person may use in concept attainment? Goodenough (1976) discusses the role of field dependence in choice of concept attainment strategies. Because of the difficulty field dependent learners have in differentiating parts from the whole, Goodenough suspected that field dependents would be more likely to choose a variation of the partist strategy—to focus on single outstanding features—to learn concepts. He offers the results of Kirschenbaum (1968), Dickstein (1968) and Shapson (1973), as support for his idea. Their experiments, using materials similar to those used by Bruner et al., (1956), all revealed a tendency for field dependents to use the less efficient strategy.

Suggestions from Concept-Attainment Theory

Concept attainment theory suggests consideration of the following factors in choice of illustration:

Instructional Pacing: The strategies employed by learners will differ depending on whether the instructional material is externally or self-paced. The number of attributes a learner may successfully use in concept attainment is a function of the time available. All other factors being equal, illustrations for externally-paced instruction should be less complex.

Previous Experience: Learners with genuine previous experience should be able to deal with greater visual complexity because of prior knowledge of many of the attributes. Less experienced learners may require simpler illustration. Learners who operate in a domain in which they believe they have knowledge may use less effective strategies because of interference of precious conceptions. Illustrations in the latter case ought to emphasize the attributes that truly define the situation.

Field Dependence: Field-dependent learners seem to employ less efficient strategies for concept attainment. Therefore, illustrations used in presenting visual concepts should be designed to assist field dependent learners use the correct features as the basis of their hypotheses.

Supportive Evidence

Some of the seemingly-conflicting results which have appeared in previous experimentation with realism in illustration provide a measure of support for the recommendations suggested by concept attainment theory. Dwyer (1972) performed a large number of studies using a lesson on heart anatomy accompanied by a variety of illustration types.

Effects of Pacing

One set of experiments used an externally-paced slide presentation as instructional method (Dwyer 1972). The general findings for these experiments indicated that line drawings provided the most effective illustration. A subsequent set of experiments used self-paced programmed instruction as the presentation medium. In contrast to the results of the experiment using externally-paced presentation, the students who performed best under this set of conditions were those who received instruction accompanied by realistic color photographs. Dwyer suggested that the photographs contain more inherent information, and the conditions of self-paced instruction are conducive to transfer. This contrast between the self-paced and externally-paced scenarios is exactly as we would expect from the suggestions of concept attainment theory.

Level of Prior Knowledge

Joseph and Dwyer (1984) tested for interaction between the degree of prior knowledge and the level of detail in instructional illustrations. For this experiment, the instructional material was once more the heart lesson, and was given in both self-paced and externally-paced formats. The researchers divided students into categories of low, medium, and high prior knowledge, based upon their performance on a physiology pretest. From this point, the experiment proceeded as did the previous experiments using the heart lesson. The experimenters concluded that:

1) Illustrations were effective in reducing differences in achievement between students with low and medium pre-test scores;

2) Illustrations did not enhance externally-paced instruction; and

3) Medium and high-level students may benefit from the use of realistic illustrations, depending on pacing and type of objective.

These results offer support for the consideration of the second factor in choice of illustration (the number of attributes to include depends in part upon the level of the learner's prior knowledge), as well as further evidence of the significance of pacing. However, since the subject material was not "thematic" and therefore unlikely to evoke preconceptions, there is little here to illuminate the role of the learner's *perceived* knowledge of the material.

Field Dependence and Visual Learning

Several researchers have sought interactions between field dependence and illustration type for a variety of tasks. Owing to the difficulty of field-dependents in articulating parts from the whole,

many experimenters have expected to find an interaction between image complexity and level of field dependence. Some examples include Canelos, Taylor and Gates (1980); Canelos (1983); Canelos and Taylor (1981); Canelos, Taylor and Altschuld (1982); and Wise (1984). None of these efforts revealed any interaction. It should be noted that none of them included an identification task among their criteria, and all focused on monochromatic images.

Moore and Dwyer (1991) examined specifically the effect of color on student performance by level of field dependence. Their hypothesis was that the addition of color cues would aid field dependent learners in picking out significant information in the illustrations. Using the same lesson on heart anatomy illustrated by either black-and-white or color-coded line drawings, they found "nonsignificant interaction ...between treatment and the three levels of interaction" (p. 614) on performance as measured using the terminology and comprehension criteria. However, the results using a visual criterion (Dwyer & Moore, 1992) revealed a greater improvement in the performance of field-dependent learners when the lesson was color-coded. The improvement placed the achievement of field-dependents very near that of field independents. Results for the groups which used the lesson illustrated with monochromatic line drawings showed a wide gap in performance, depending on level of field-dependence. It appears that the emphasis color-coding places on definitive attributes may assist field-dependent learners to identify them.

Moore and Dwyer have demonstrated that for objectives which have a visual component, color cues may provide significant help for field-dependent learners. However, their objectives did not include a determination of possible interaction of illustration type with field-dependence for an identification task. French (1984) conducted just such an experiment. With a learner population of 492 trade apprentices, she examined the effects of detail in illustration on the ability of field-dependents and field-independents to learn to identify five types of diesel fuel injectors. The illustrations were either color-coded or black-and-white, simple or complex line-drawings. The presentation of material was by an externally-paced audio tape and filmstrip. Criteria for performance were first a task of identifying (classifying) an assortment of drawings of fuel injectors, and a second task in which the learner classified *real* fuel injectors.

French's results suggest that simple color-coded line drawings provided learning assistance for field dependent students, although color-cueing did not confer any advantage in general. This agrees with the findings of Dwyer and Moore (1992).

Conclusion

It has long been believed that the addition of illustrations to any effort to communicate enhances the effectiveness of the communication. Investigators have attempted to use cue-summation theory to predict in which instances illustrations of various types would prove most effective. Unfortunately, results from these efforts have been varied. One question unaddressed by these

studies is how to choose *which* (attributes) to include or emphasize in illustration.

Concept attainment theory provides a means for selecting which cues to include in visuals based on understanding of the level of previous experience, the pacing of the lesson, and learner's individual differences. Application of concept attainment to previous results provides explanation for much of the variation which has previously confounded the research. Furthermore, inclusion of this theory in future efforts may allow much more precise and informed choices of illustrations, as well as suggesting use of types of illustration previously left unconsidered.

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